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**Manssour et al.**

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(45) **Date of Patent: Feb. 2, 2016**

(54) **EFFICIENT SPECTRUM UTILIZATION WITH ALMOST BLANK SUBFRAMES**

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(73) Assignee: **Telefonaktiebolaget L M Ericsson (publ)**, Stockholm (SE)

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(22) Filed: **Dec. 2, 2011**

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(51) **Int. Cl.**

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| ***H04W 72/12*** | (2009.01) |
| *H04W 84/04* | (2009.01) |

(52) **U.S. Cl.**

CPC ..... ***H04W 72/1252*** (2013.01); *H04W 84/045* (2013.01)

(58) **Field of Classification Search**

CPC ..... H04W 84/045; H04W 72/1252
USPC ..... 370/336
See application file for complete search history.

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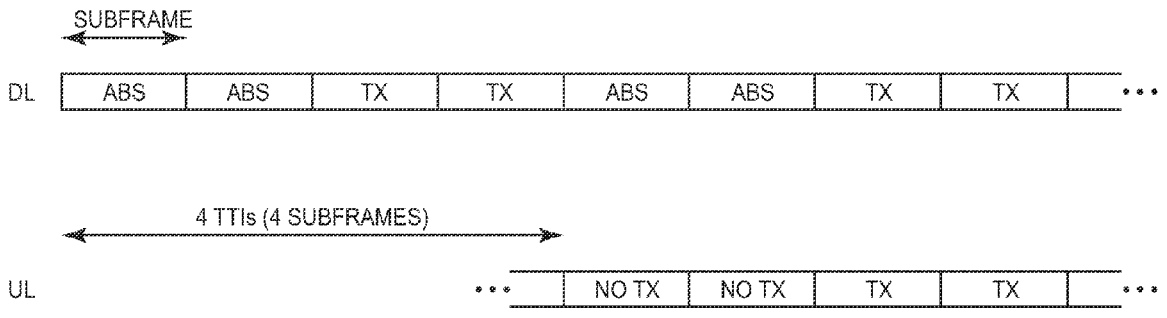
*Primary Examiner* — Jung Park
*Assistant Examiner* — Albert Shih
(74) *Attorney, Agent, or Firm* — Withrow & Terranova, PLLC

(57) **ABSTRACT**

Systems and methods for providing efficient utilization of spectrum in a cellular communication network that applies Almost Blank Subframes (ABSs) are disclosed. In general, the network includes an access node that applies ABSs in the downlink. In one embodiment, the access node identifies UEs for which transmissions are to be scheduled for the uplink using a scheduling scheme that does not require control information for every subframe. The access node then time-aligns scheduling instants of the UEs and subframes in the uplink that correspond to at least some of the ABSs in the downlink. In another embodiment, the access node identifies UEs for which transmissions are to be scheduled for the downlink using a scheduling scheme that does not require control information for every subframe. The access node then time-aligns scheduling instants of the UEs for the downlink and at least a subset of the ABSs in the downlink.

**43 Claims, 14 Drawing Sheets**



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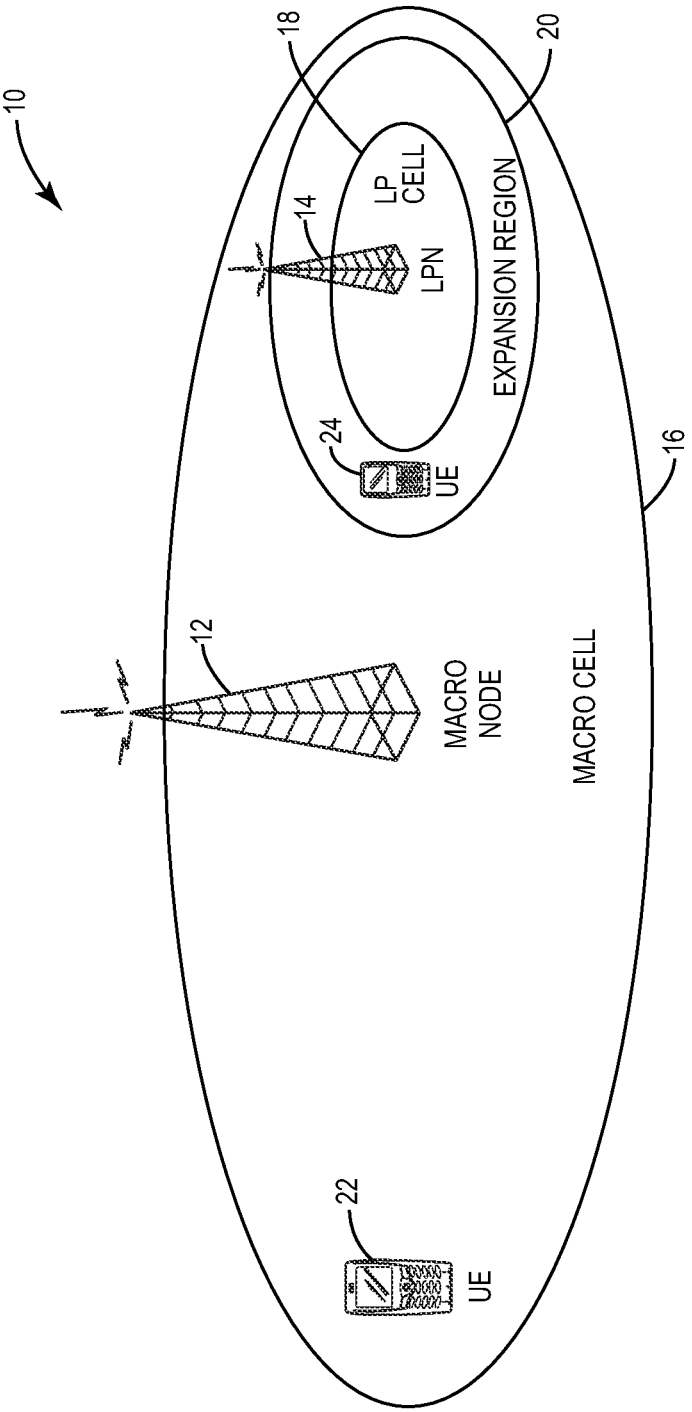
10
18
20
LP CELL
14
LPN
EXPANSION REGION
24
UE
16
12
MACRO NODE
MACRO CELL
22
UE

FIG. 1

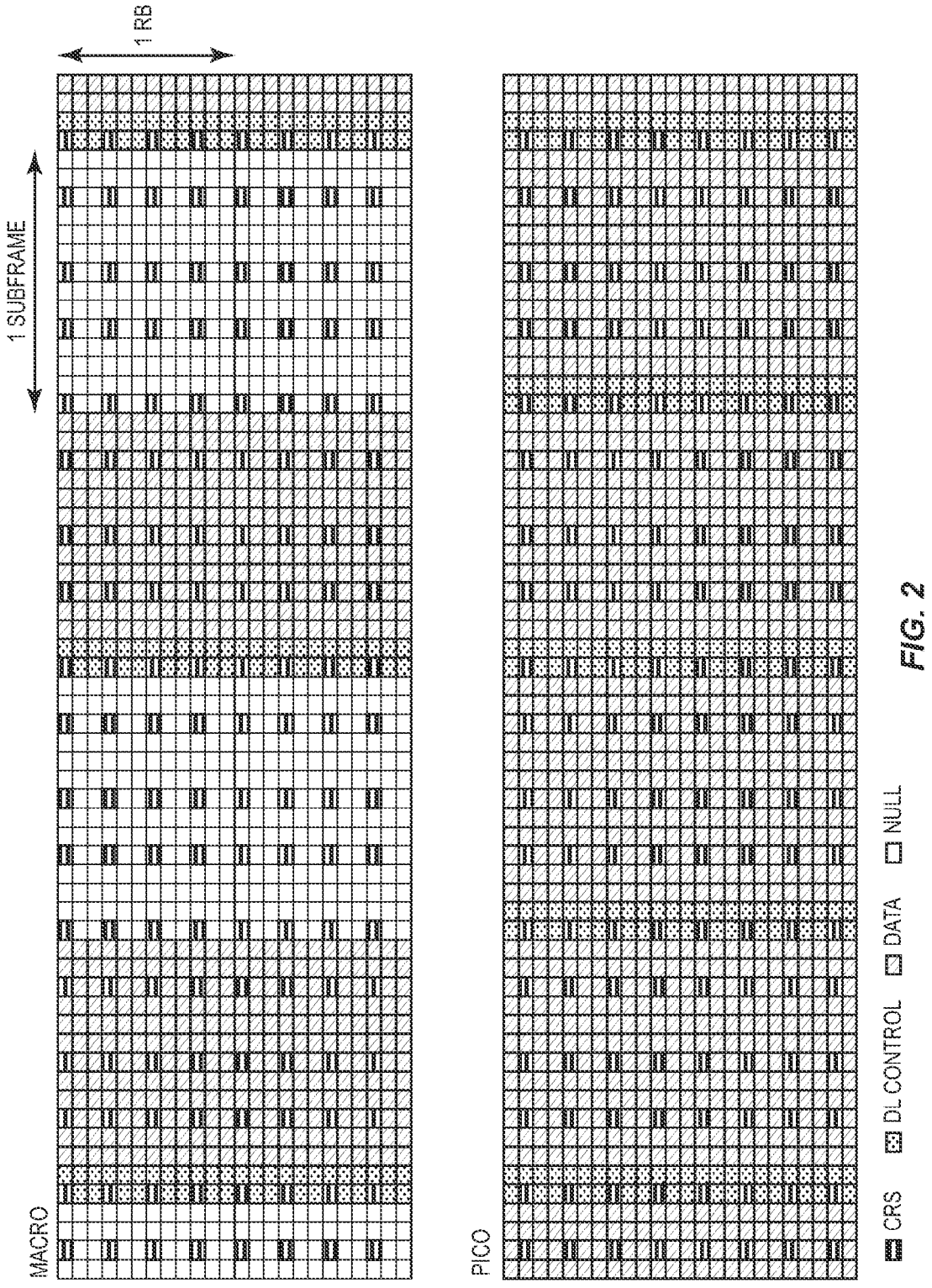


FIG. 2

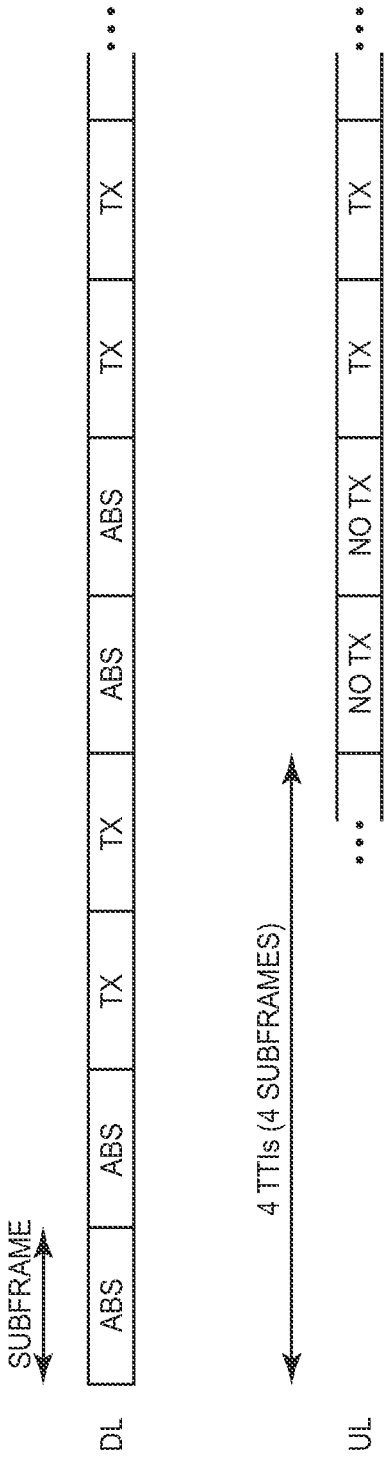
SUBFRAME
DL
ABS
ABS
TX
TX
ABS
ABS
TX
TX
...
4 TTIs (4 SUBFRAMES)
UL
...
NO TX
NO TX
TX
TX
...

FIG. 3

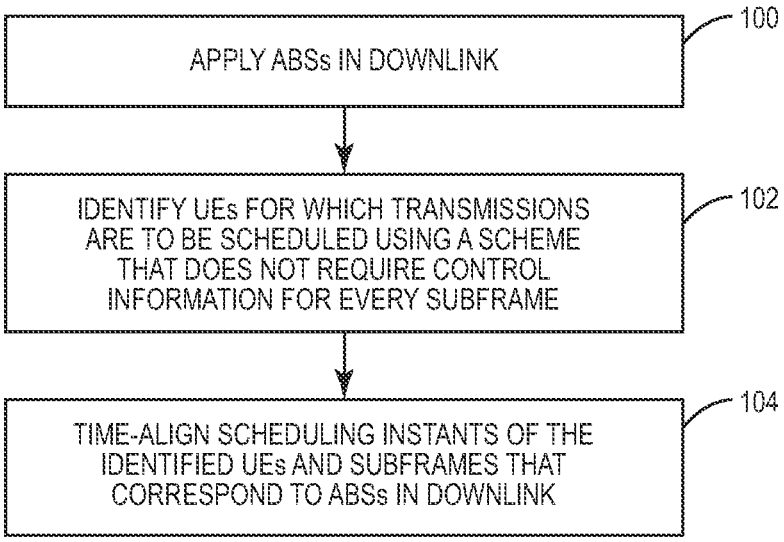
APPLY ABSs IN DOWNLINK
100
IDENTIFY UEs FOR WHICH TRANSMISSIONS ARE TO BE SCHEDULED USING A SCHEME THAT DOES NOT REQUIRE CONTROL INFORMATION FOR EVERY SUBFRAME
102
TIME-ALIGN SCHEDULING INSTANTS OF THE IDENTIFIED UEs AND SUBFRAMES THAT CORRESPOND TO ABSs IN DOWNLINK
104

*FIG. 4*

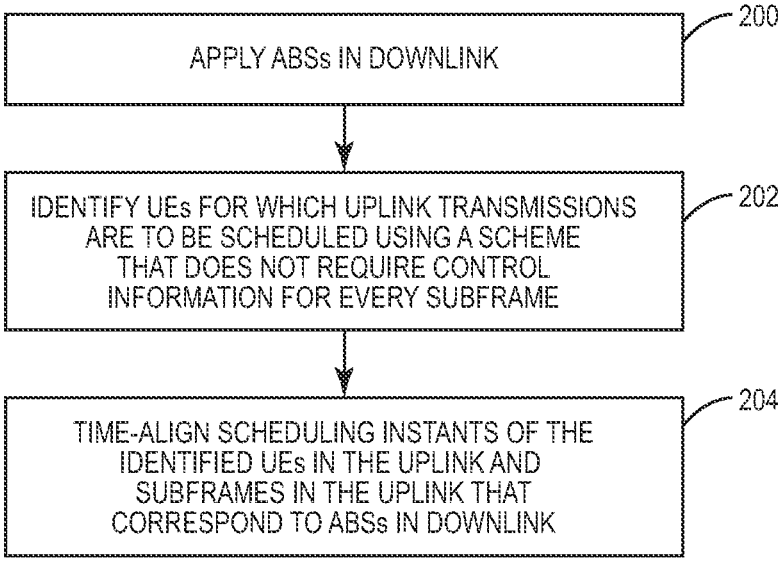
APPLY ABSs IN DOWNLINK
200
IDENTIFY UEs FOR WHICH UPLINK TRANSMISSIONS ARE TO BE SCHEDULED USING A SCHEME THAT DOES NOT REQUIRE CONTROL INFORMATION FOR EVERY SUBFRAME
202
TIME-ALIGN SCHEDULING INSTANTS OF THE IDENTIFIED UEs IN THE UPLINK AND SUBFRAMES IN THE UPLINK THAT CORRESPOND TO ABSs IN DOWNLINK
204

*FIG. 5*

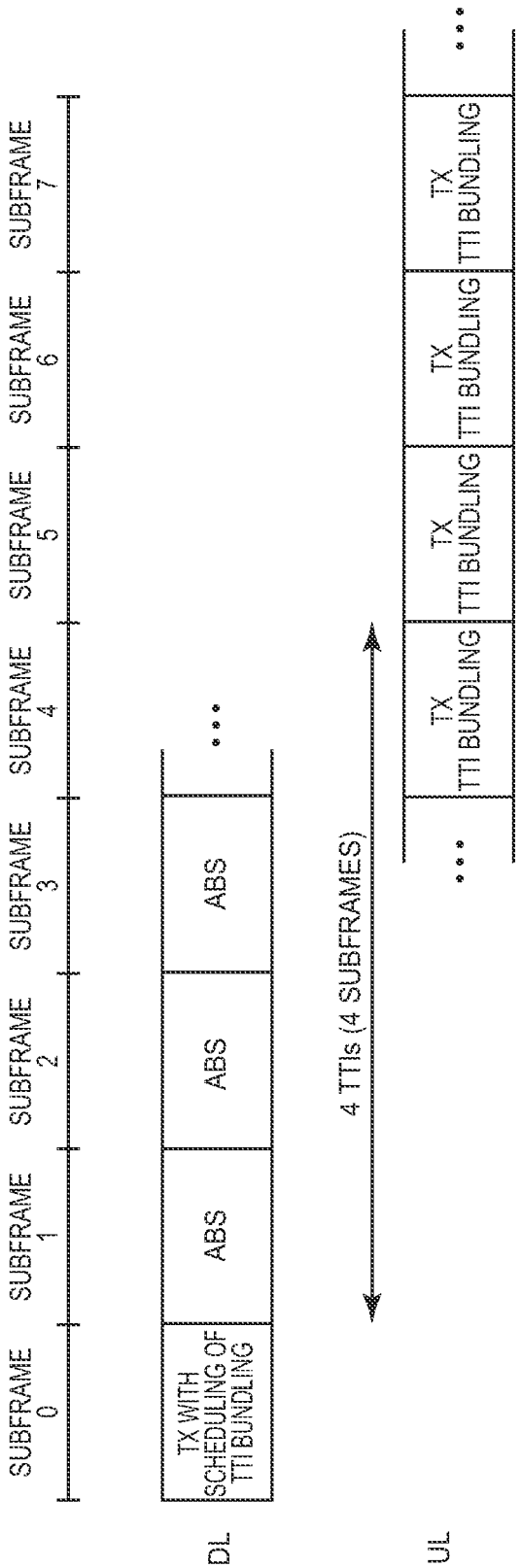
SUBFRAME 0
SUBFRAME 1
SUBFRAME 2
SUBFRAME 3
SUBFRAME 4
SUBFRAME 5
SUBFRAME 6
SUBFRAME 7
DL
TX WITH SCHEDULING OF TTI BUNDLING
ABS
ABS
ABS
• • •
4 TTIs (4 SUBFRAMES)
UL
• • •
TX TTI BUNDLING
TX TTI BUNDLING
TX TTI BUNDLING
TX TTI BUNDLING
• • •

FIG. 6

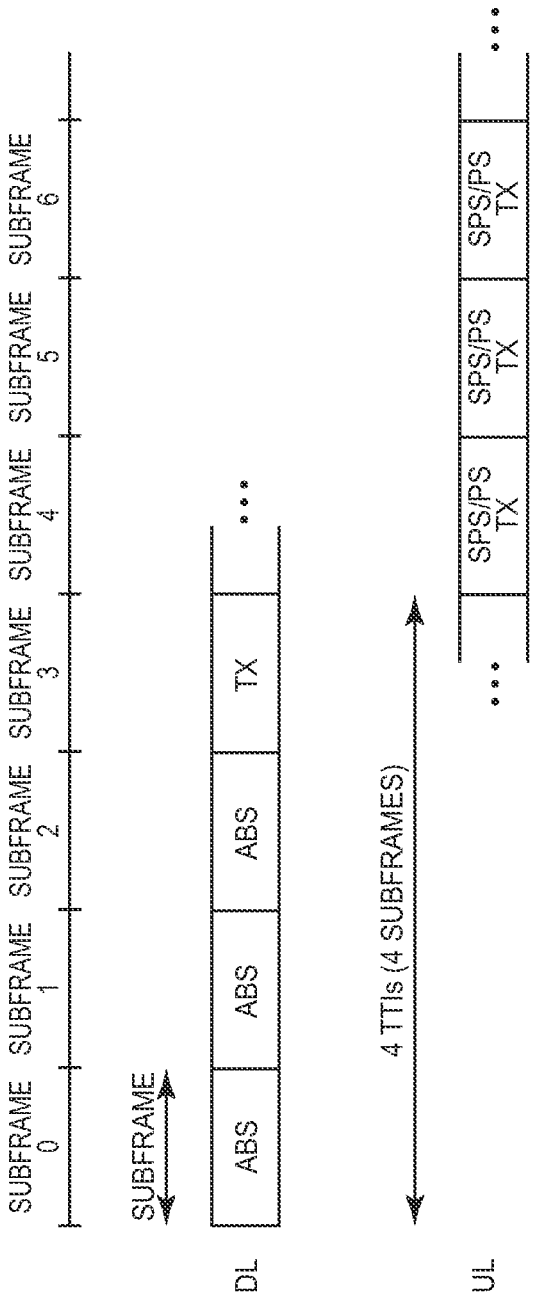
SUBFRAME 0
SUBFRAME 1
SUBFRAME 2
SUBFRAME 3
SUBFRAME 4
SUBFRAME 5
SUBFRAME 6
SUBFRAME
DL
ABS
ABS
ABS
TX
...
4 TTIs (4 SUBFRAMES)
UL
...
SPS/PS TX
SPS/PS TX
SPS/PS TX
...

FIG. 7

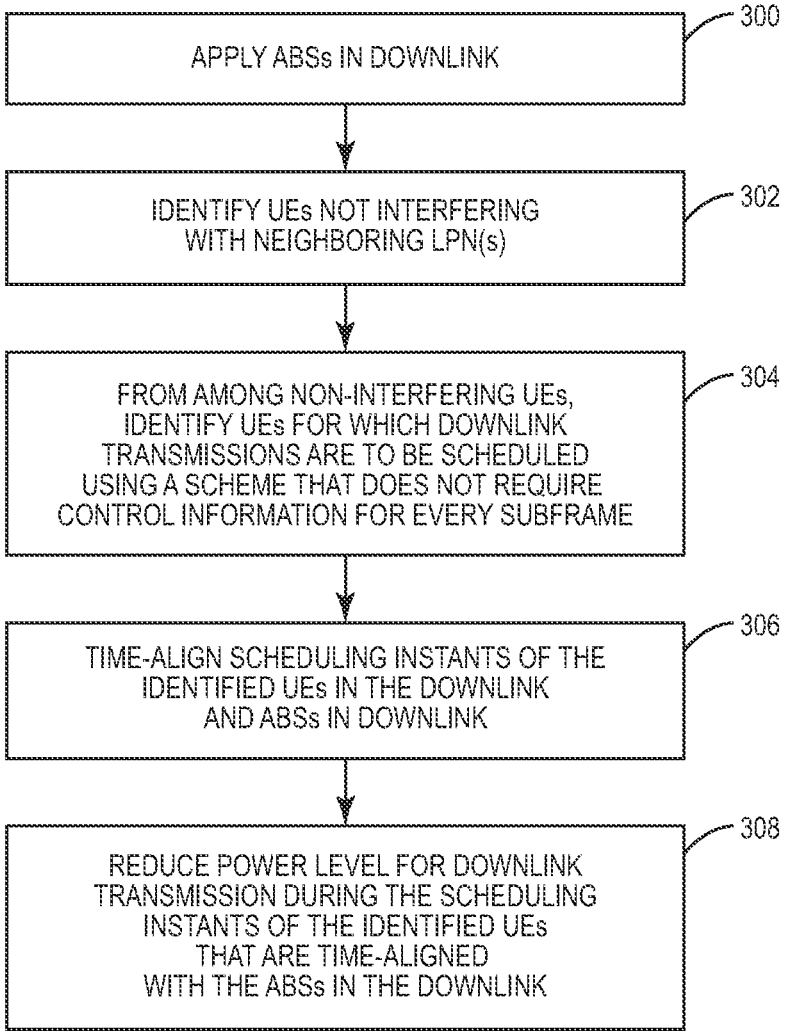
APPLY ABSs IN DOWNLINK
300
IDENTIFY UEs NOT INTERFERING WITH NEIGHBORING LPN(s)
302
FROM AMONG NON-INTERFERING UEs, IDENTIFY UEs FOR WHICH DOWNLINK TRANSMISSIONS ARE TO BE SCHEDULED USING A SCHEME THAT DOES NOT REQUIRE CONTROL INFORMATION FOR EVERY SUBFRAME
304
TIME-ALIGN SCHEDULING INSTANTS OF THE IDENTIFIED UEs IN THE DOWNLINK AND ABSs IN DOWNLINK
306
REDUCE POWER LEVEL FOR DOWNLINK TRANSMISSION DURING THE SCHEDULING INSTANTS OF THE IDENTIFIED UEs THAT ARE TIME-ALIGNED WITH THE ABSs IN THE DOWNLINK
308

*FIG. 8*

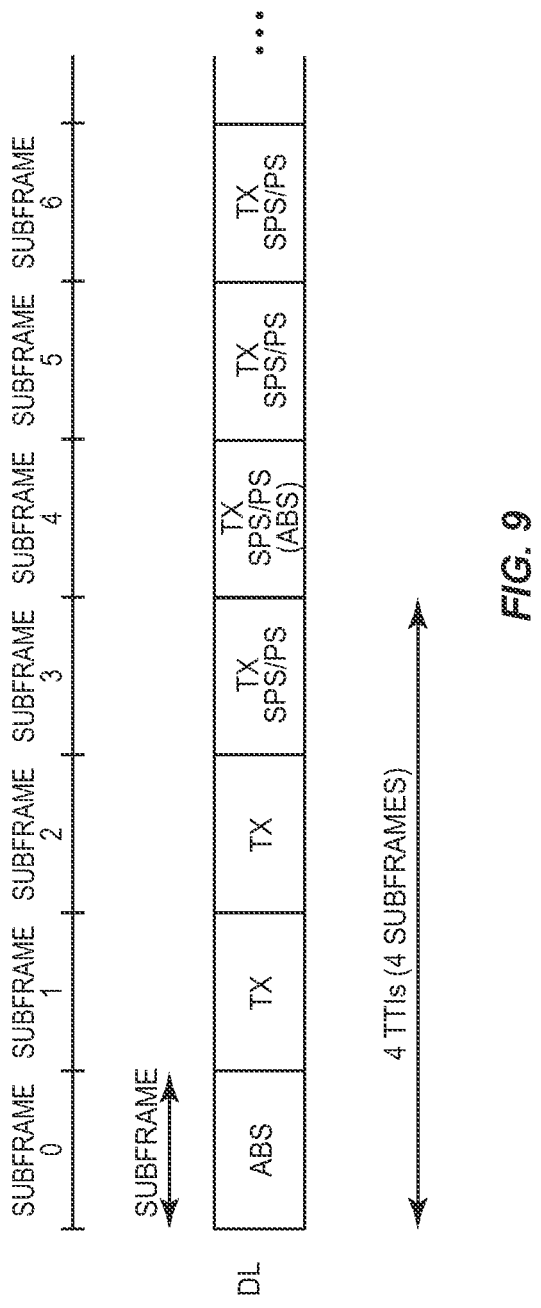
SUBFRAME 0
SUBFRAME 1
SUBFRAME 2
SUBFRAME 3
SUBFRAME 4
SUBFRAME 5
SUBFRAME 6
SUBFRAME
DL
ABS
TX
TX
TX SPS/PS
TX SPS/PS (ABS)
TX SPS/PS
TX SPS/PS
...
4 TTIs (4 SUBFRAMES)

FIG. 9

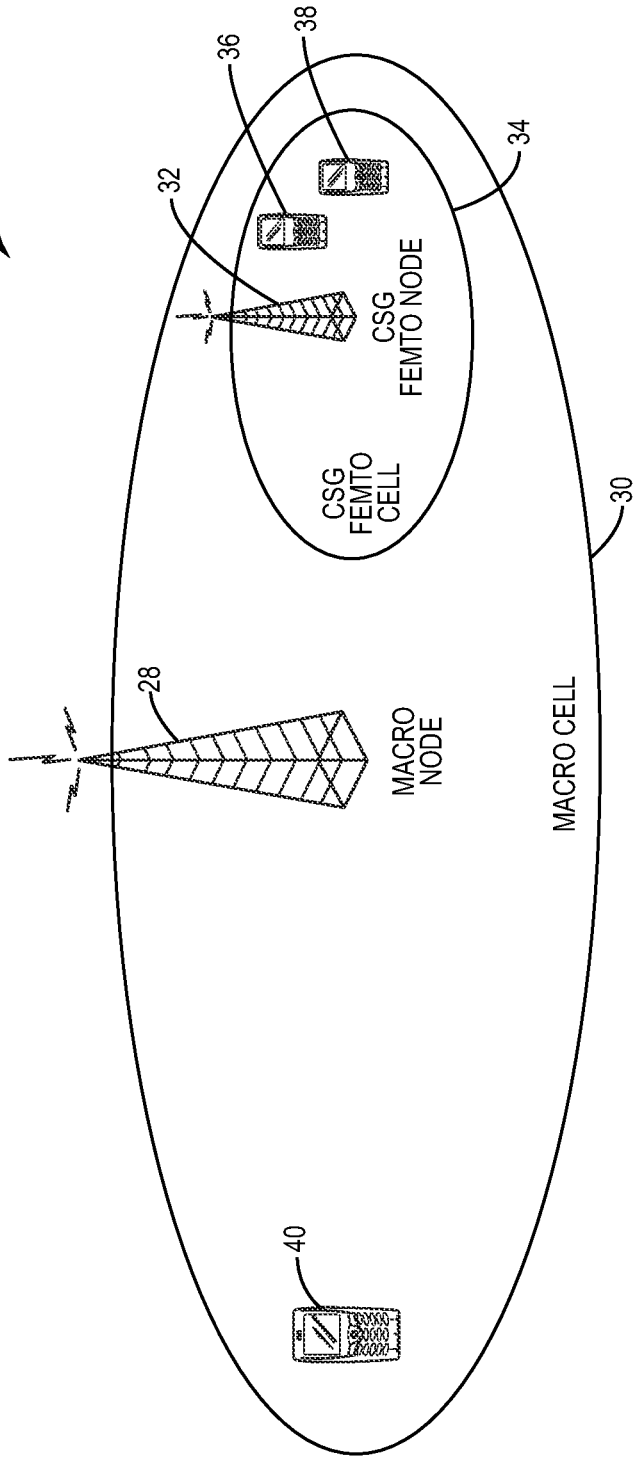
26
28
30
32
34
36
38
40
MACRO NODE
MACRO CELL
CSG FEMTO CELL
CSG FEMTO NODE

FIG. 10

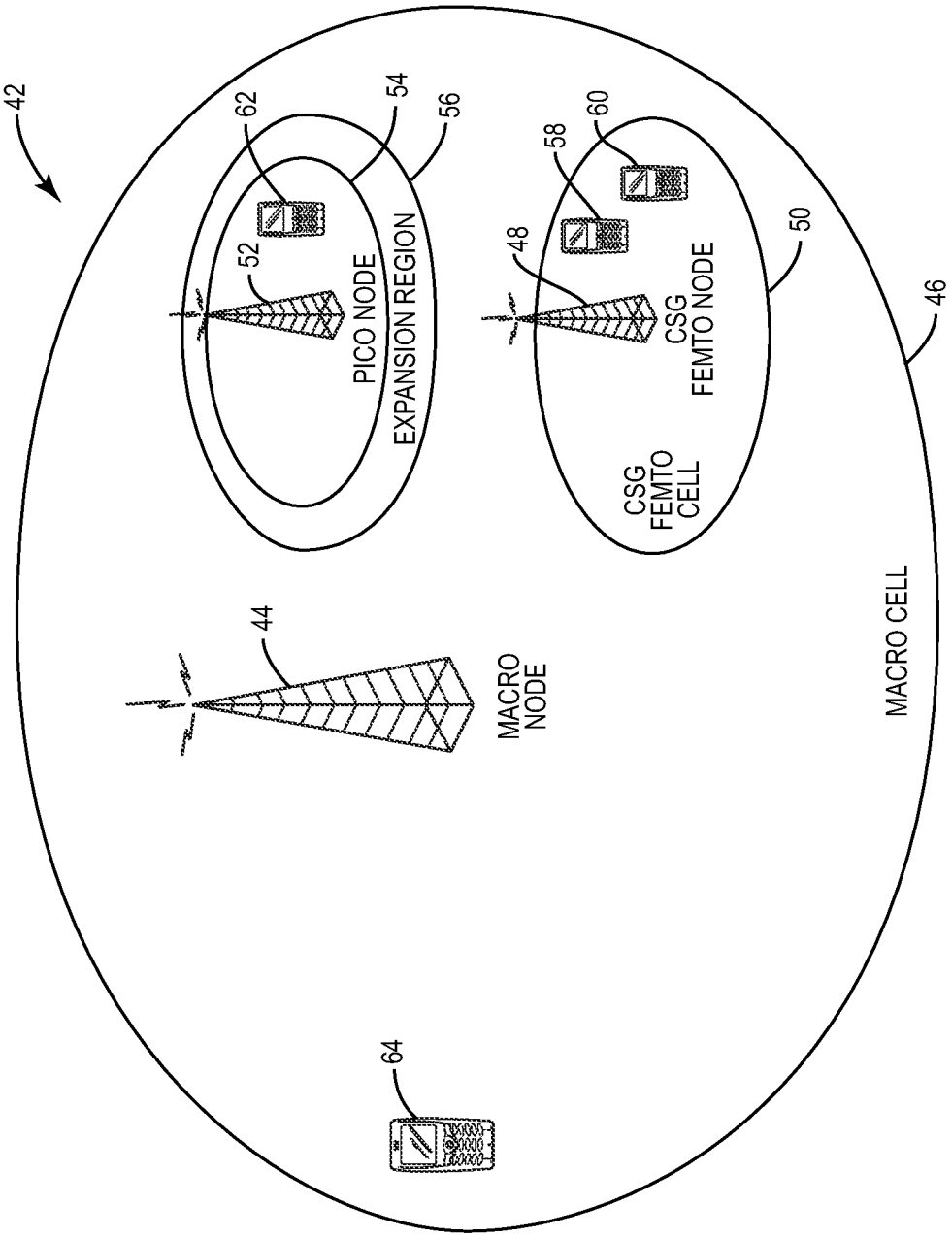
42
62
54
56
52
PICO NODE
EXPANSION REGION
58
60
48
CSG
FEMTO NODE
50
CSG
FEMTO
CELL
46
44
MACRO
NODE
MACRO CELL
64

FIG. 11

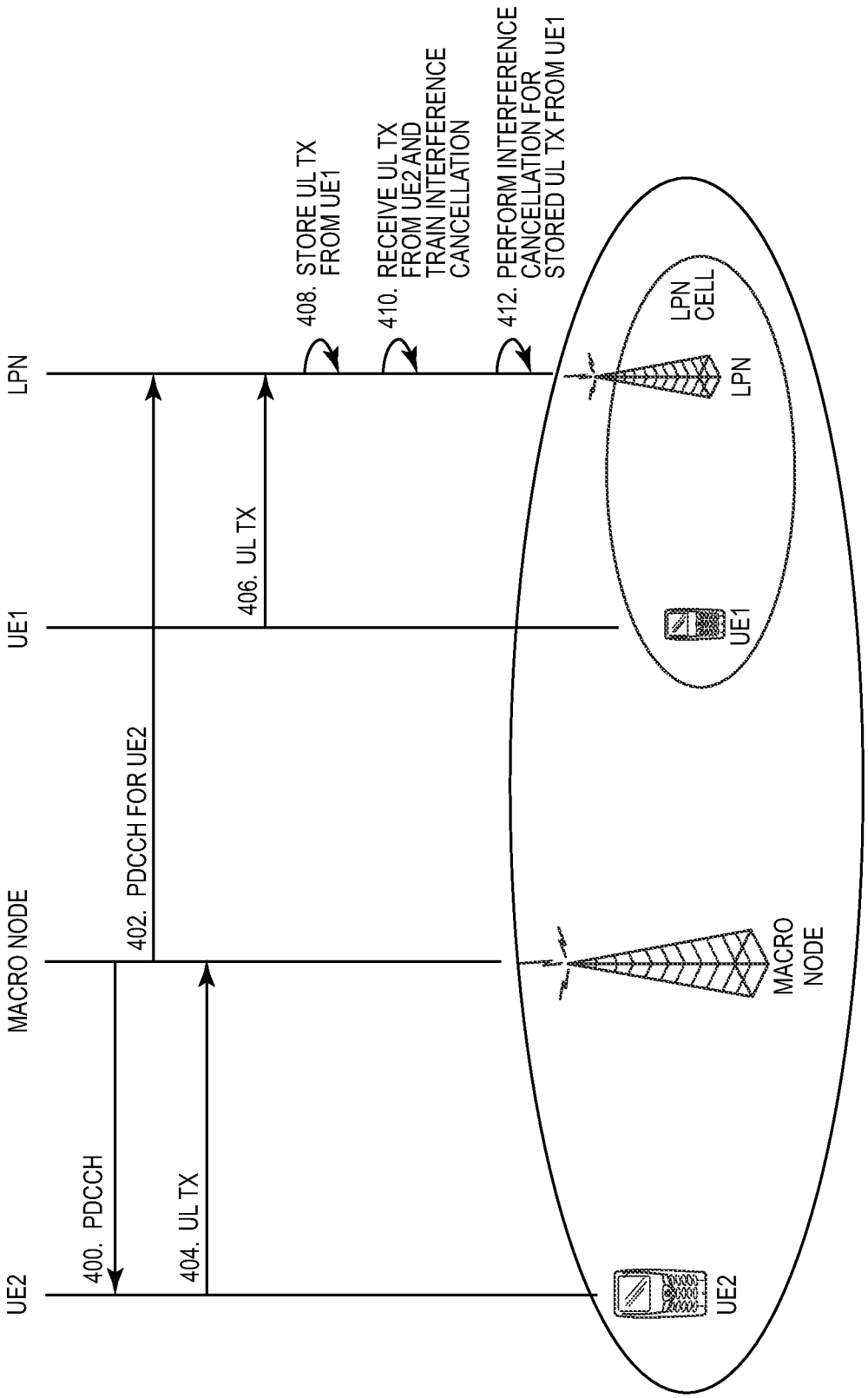
LPN
UE1
MACRO NODE
UE2
400. PDCCH
402. PDCCH FOR UE2
404. UL TX
406. UL TX
408. STORE UL TX FROM UE1
410. RECEIVE UL TX FROM UE2 AND TRAIN INTERFERENCE CANCELLATION
412. PERFORM INTERFERENCE CANCELLATION FOR STORED UL TX FROM UE1
LPN CELL
LPN
UE1
MACRO NODE
UE2

FIG. 12

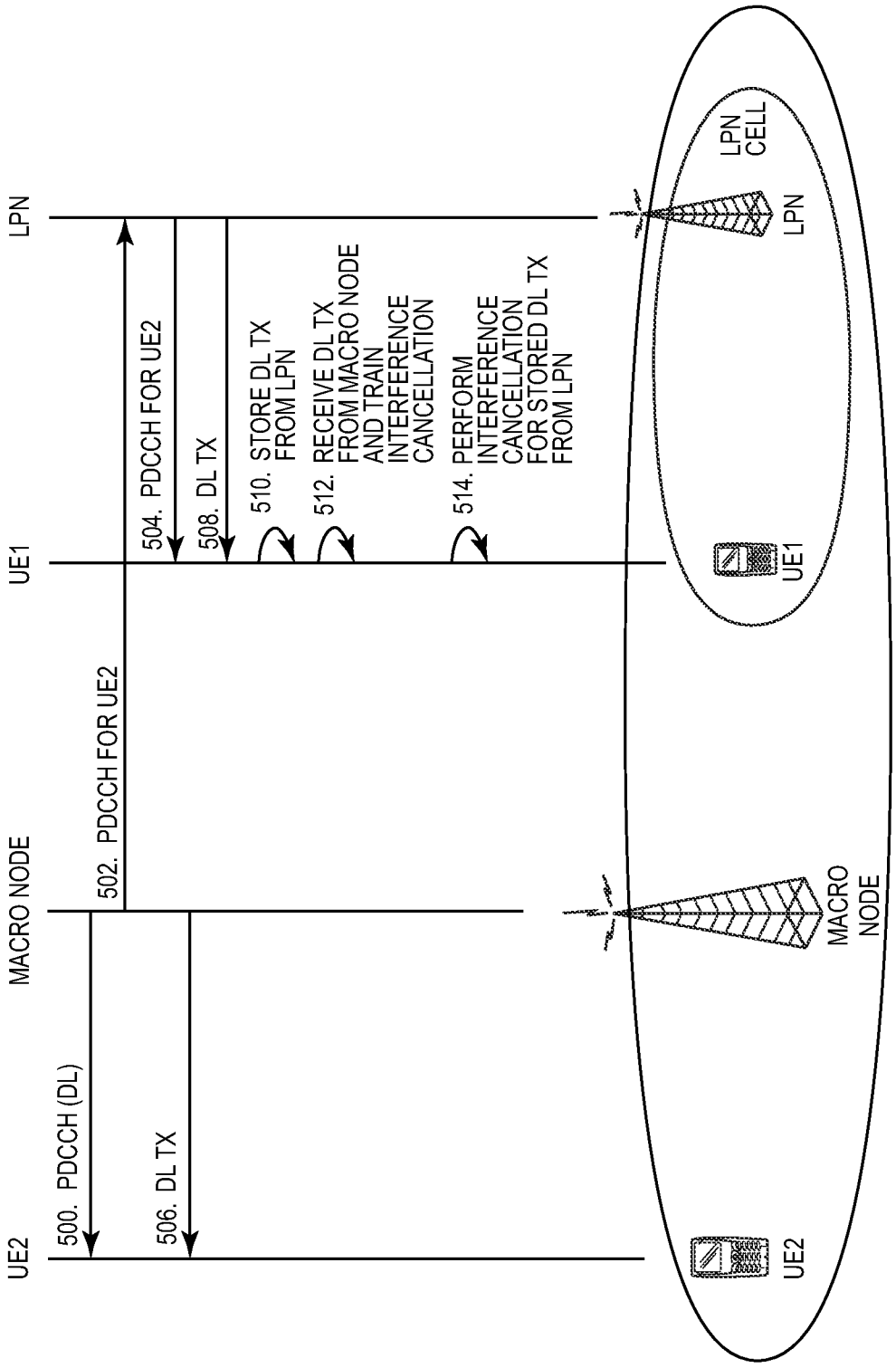
LPN
UE1
MACRO NODE
UE2
500. PDCCH (DL)
502. PDCCH FOR UE2
504. PDCCH FOR UE2
506. DL TX
508. DL TX
510. STORE DL TX FROM LPN
512. RECEIVE DL TX FROM MACRO NODE AND TRAIN INTERFERENCE CANCELLATION
514. PERFORM INTERFERENCE CANCELLATION FOR STORED DL TX FROM LPN
LPN CELL
LPN
UE1
MACRO NODE
UE2

FIG. 13

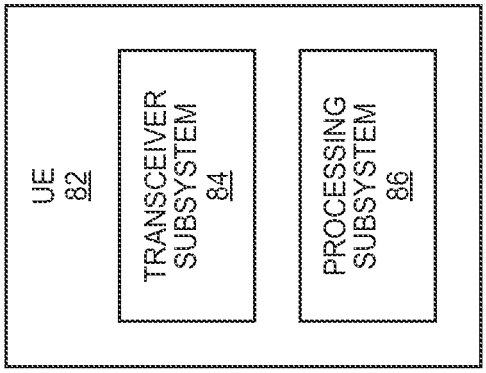


FIG. 16

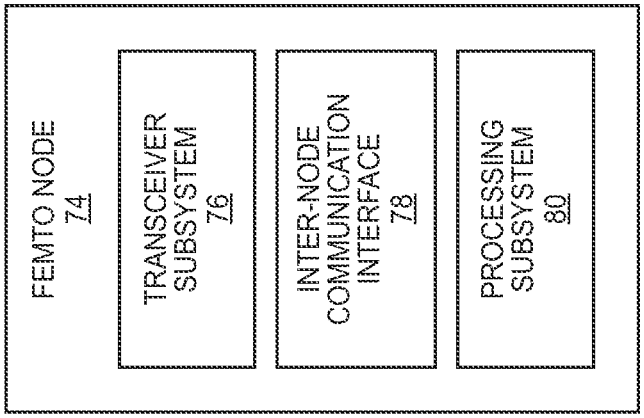


FIG. 15

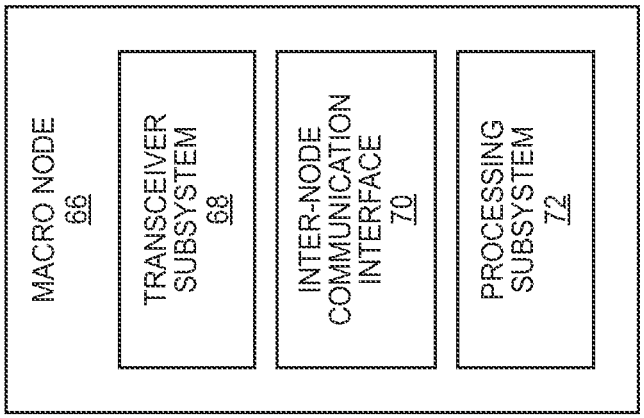


FIG. 14

# EFFICIENT SPECTRUM UTILIZATION WITH ALMOST BLANK SUBFRAMES

## FIELD OF THE DISCLOSURE

The present disclosure relates to a cellular communication network and more particularly relates to efficient spectrum utilization when applying almost blank subframes in a downlink from an access node (e.g., a macro node or a Closed Subscriber Group (CSG) femto node) in a heterogeneous cellular communication network.

## BACKGROUND

The deployment of heterogeneous cellular communication networks, which are referred to herein as Heterogeneous Networks (HetNets), is largely seen as one of the most cost efficient solutions to meeting the constantly increasing demand for higher data rates in the coming generations of cellular systems. Such deployments include several Low Power Nodes (LPNs) of diverse nature (e.g., micro, pico, and femto eNode Bs in the case of 3GPP Long Term Evolution (LTE)). These LPNs transform conventional homogeneous cellular communication network architecture into a fragmented multi-layered architecture.

HetNets are resistant to strains on signal power normally resulting from increasing distance from the transmitting point and are well known to defy the inverse square law of distance by moving base stations (BSs) (i.e., macro nodes and the LPNs) closer to user equipment devices (UEs) and providing similar Quality-of-Service (QoS) throughout the cell area. Thus, HetNet deployments possess an inherent capability to address the limitations implied by channel capacity and provide a uniform user experience throughout the cell area irrespective of user location. The potential of HetNets to bring gains in coverage and capacity are widely acknowledged. The major advantages or benefits can be summarized as:

- Moving the BSs closer to the UEs results in better radio link conditions which in turn leads to higher data rates for UEs connected to LPNs.
- LPN cells provide access to the UEs previously handled by the macro layer, thus reducing the load from the macro cell (called macro offloading) which results in higher availability of resources and thus higher data rates for the users connected to macro nodes.
- In general, HetNet deployments provide uniform data rates within a given area.

However, even though there are significant advantages brought by HetNet architectures, there are a number of concerns to be addressed. For instance, the high number of parameters associated with LPNs, e.g., restrictions on transmission power, access rights, and backhaul capacities, has a direct impact on system performance and makes the selection of LPN type and supported features a highly complicated task. The decision depends mainly on the goal to be achieved with the addition of LPNs (e.g., capacity vs. data rate improvement, or both).

The co-existence of cells with different power levels in HetNets has several implications on system access and mobility procedures. In a macro-only deployment, the cell selection process for the UEs is generally based on the Reference Signal Received Power (RSRP), otherwise known as Received Signal Strength (RSS). This means that the UEs get attached to the cell from which they attain strongest RSS. However, employing this access procedure to HetNets can intensify the interference scenarios in the uplink and can further lead to load imbalance situations where most of the



UEs get connected to macro cells while LPN cells are underutilized. In LTE, the power difference between the macro and femto cells is about 23 decibel-milliwatts (dBm). This means that UEs that have a lower path loss to the LPN cell still receive high RSRP from the macro node and therefore are connected to the macro node rather than the LPN. This causes high interference in the uplink, which results in an uneven distribution of UEs in the macro and LPN cell layer.

The aforementioned load imbalance issue has been a topic of several researches. One proposed solution is a concept of "Range Extension" which provides a simulated expansion in the range of the LPN when making a decision on UE association with the LPN. This means that whenever a UE is associating to a LPN, an artificial offset threshold is to be added to the actual RSRP value to be used for the cell association decision. In contrast, in the case of macro node, the association decisions are based on the actual received signal strength in most of the cases. The concept of Range Extension (RE) enables an optimal association of users throughout the coverage area, which leads to enhanced system performance and load reduction from the macro cell at the same time.

The drawback of range extension is that UEs located in the extended range of small cells and connected to LPNs might experience difficulties in correctly receiving downlink control information transmitted by the downlink. Specifically, for LTE, UEs located in the extended range of LPNs and connected to LPNs may experience difficulty in correctly receiving downlink control information in the Physical Downlink Control Channel (PDCCH) since those UEs are experiencing negative downlink geometry. To minimize the effect of high interference onto the PDCCH transmitted by the LPN, Almost Blank Subframes (ABSs) are used. During ABSs at the macro node, there is no data transmission from the macro node, which provides the advantage of low interference to LPN cells.

During an ABS at the macro node, the transmission from the macro node does not contain data or control information, but mainly Common, or Cell-Specific, Reference Signal (CRS). This means that the corresponding uplink subframe (i.e., for LTE, the uplink subframe that occurs 4 Transmit Time Intervals (TTIs) later) in the macro node will have no data transmission either because no Downlink Control Information (DCI) (or control information in general) was transmitted in downlink during the ABS. As a result, resources are not fully utilized leading to a decrease in capacity and spectral efficiency.

## SUMMARY

The present disclosure relates to systems and methods that provide efficient utilization of spectrum in a cellular communication network that applies almost blank subframes. In the preferred embodiment, the cellular communication network is a heterogeneous cellular communication network (HetNet). In one embodiment, the HetNet includes an access node that applies almost blank subframes in a downlink from the access node to user equipment devices (UEs) served by the access node. In one particular embodiment, the access node is a macro node. In another particular embodiment, the access node is a femto node, such as a Closed Subscriber Group (CSG) femto cell. Almost blank subframes do not include control information. In order to provide efficient spectrum utilization when using almost blank subframes in the downlink, the access node identifies one or more UEs for which transmissions are to be scheduled using a scheduling scheme that does not require control information for every subframe.

Some exemplary scheduling schemes that do not require control information for every subframe are Transmit Time Interval (TTI) bundling, Semi-Persistent Scheduling (SPS), and Persistent Scheduling (PS). The access node then time-aligns scheduling instants of the one or more UEs and subframes that correspond to at least some of the almost blank subframes in the downlink. In this manner, at least some of the subframes that would normally have no scheduled transmissions as a result of the lack of control information in the almost blank subframes are utilized by the scheduling instants for the one or more UEs.

In one embodiment, in order to provide efficient spectrum utilization in the uplink, the access node identifies one or more UEs for which transmissions are to be scheduled for the uplink using a scheduling scheme that does not require control information for every subframe. Some exemplary scheduling schemes that do not require control information for every subframe are TTI bundling, SPS, and PS. The access node then time-aligns scheduling instants of the one or more UEs and subframes in the uplink that correspond to at least some of the almost blank subframes in the downlink. For the uplink, the subframes in the uplink that correspond to at least some of the almost blank subframes are subframes that occur in the uplink a predefined amount of time after the at least some of the almost blank subframes. In this manner, at least some of the subframes in the uplink that would normally have no scheduled transmissions as a result of the lack of control information in the almost blank subframes are utilized by the scheduling instants for the one or more UEs.

In another embodiment, in order to provide efficient spectrum utilization for the downlink, the access node identifies one or more UEs for which transmissions are to be scheduled for the downlink using a scheduling scheme that does not require control information for every subframe. Some exemplary scheduling schemes that do not require control information for every subframe are SPS and PS. The access node then time-aligns scheduling instants of the one or more UEs for the downlink and at least a subset of the almost blank subframes in the downlink. In this manner, at least some of the almost blank subframes in the downlink that would normally have no scheduled transmissions as a result of the lack of control information in the almost blank subframes are utilized by the scheduling instants for one or more UEs.

Those skilled in the art will appreciate the scope of the present disclosure and realize additional aspects thereof after reading the following detailed description of the preferred embodiments in association with the accompanying drawing figures.

## BRIEF DESCRIPTION OF THE DRAWING FIGURES

The accompanying drawing figures incorporated in and forming a part of this specification illustrate several aspects of the disclosure, and together with the description serve to explain the principles of the disclosure.

FIG. **1** illustrates a heterogeneous cellular communication network (HetNet) including a macro node and a Low Power Node (LPN) according to one embodiment of the present disclosure;

FIG. **2** illustrates exemplary Almost Blank Subframes (ABSs) applied to a downlink from the macro node of FIG. **1**;

FIG. **3** illustrates an exemplary downlink from the macro node including ABSs and an exemplary uplink to the macro node where the uplink includes subframes in which no transmissions are normally scheduled as a result of the ABSs in the downlink from the macro node;

FIG. **4** illustrates the operation of the macro node of FIG. **1** to provide efficient spectrum utilization when applying ABSs in the downlink by time-aligning scheduling instants for one or more user equipment devices (UEs) for which transmissions are scheduled according to a scheduling scheme that does not require control information for every subframe according to one embodiment of the present disclosure;

FIG. **5** illustrates the operation of the macro node of FIG. **1** to provide efficient spectrum utilization for the uplink when applying ABSs in the downlink according to one embodiment of the present disclosure;

FIG. **6** graphically illustrates time alignment of Transmit Time Interval (TTI) bundles for one or more UEs and subframes in the uplink that correspond to ABSs in the downlink according to one embodiment of the process of FIG. **5**;

FIG. **7** graphically illustrates time alignment of semi-persistent or persistent scheduling instants of one or more UEs and subframes in the uplink that correspond to ABSs in the downlink according to one embodiment of the process of FIG. **5**;

FIG. **8** illustrates the operation of the macro node of FIG. **1** to provide efficient spectrum utilization for the downlink when applying ABSs in the downlink according to one embodiment of the present disclosure;

FIG. **9** graphically illustrates time alignment of semi-persistent or persistent scheduling instants of one or more UEs and subframes in the downlink that correspond to ABSs in the downlink according to one embodiment of the process of FIG. **8**;

FIG. **10** illustrates a HetNet including a macro node and a Closed Subscriber Group (CSG) femto node according to another embodiment of the present disclosure;

FIG. **11** illustrates a HetNet including a macro node, a CSG femto node, and a pico node according to another embodiment of the present disclosure;

FIG. **12** illustrates a HetNet that provides uplink interference cancellation according to one embodiment of the present disclosure;

FIG. **13** illustrates a HetNet that provides downlink interference cancellation according to one embodiment of the present disclosure;

FIG. **14** is a block diagram of a macro node according to one embodiment of the present disclosure;

FIG. **15** is a block diagram of a femto node according to one embodiment of the present disclosure; and

FIG. **16** is a block diagram of a user equipment device according to one embodiment of the present disclosure.

## DETAILED DESCRIPTION

The embodiments set forth below represent the necessary information to enable those skilled in the art to practice the embodiments and illustrate the best mode of practicing the embodiments. Upon reading the following description in light of the accompanying drawing figures, those skilled in the art will understand the concepts of the disclosure and will recognize applications of these concepts not particularly addressed herein. It should be understood that these concepts and applications fall within the scope of the disclosure and the accompanying claims.

The present disclosure relates to systems and methods that provide efficient utilization of spectrum in a heterogeneous cellular communication network (HetNet) that applies almost blank subframes (ABSs). FIG. **1** illustrates a heterogeneous cellular communication network **10** (hereinafter HetNet **10**) according to one embodiment of the present disclosure. The discussion below focuses on embodiments where the HetNet

10 operates according to a Long Term Evolution (LTE) standard. Note, however, that the concepts discussed herein are applicable to any type of HetNet 10 that uses ABSs.

As illustrated, the HetNet 10 includes a macro node 12 and a Low Power Node (LPN) 14. The macro node 12 is a base station (e.g., macro eNode B) that serves a corresponding macro cell 16. The LPN 14 is also a base station but transmits at a substantially lower power level than the macro node 12. In addition, the LPN 14 may have other characteristics that are different than those of the macro node 12 (e.g., a different number of antennas). The LPN 14 may be, for example, a micro, pico, or femto eNode B. The LPN 14 serves a corresponding Low Power (LP) cell 18. In addition, the LPN 14 serves an expansion region 20 that surrounds the LP cell 18. The expansion region 20 is a region in which a path loss to the LPN 14 is less than a path loss to the macro node 12 but where a received strength of signal from the macro node 12 is greater than a received strength of signal from the LPN 14. In the illustrated example, a user equipment device (UE) 22 is located in the macro cell 16 and is served by the macro node 12, and a UE 24 is located in the expansion region 20 and is served by the LPN 14. Preferably, transmissions to and from the macro node 12 are synchronized with transmissions to and from the LPN 14.

As discussed below in detail, the macro node 12 applies ABSs in a downlink from the macro node 12. In general, ABSs do not include control information. In one particular embodiment, ABSs do not include control information and also do not include data. However, in another embodiment, ABSs may be either normal power ABSs that do not include control information and do not include data or low power ABSs that do not include control information but do include data. Low power ABSs are transmitted at a low transmit power to reduce interference. The ABSs provide an advantage in that interference particularly for UEs, such as the UE 24, located in the expansion region 20 is reduced. Reduced interference improves the ability of UEs, such as the UE 24, located in the expansion region 20 to successfully receive a Physical Downlink Control Channel (PDCCH) from the LPN 14.

FIG. 2 illustrates exemplary ABSs in the downlink from the macro node 12. In this example, no data and no control information is transmitted in the ABSs. For instance, for LTE, the ABSs do not include any data transmitted on the Physical Downlink Shared Channel (PDSCH)) or control information transmitted on the Downlink Control Information (DCI) channel. As a result, interference to the UEs, such as the UE 24, located in the expansion region 20 is substantially reduced during the ABSs in the downlink from the macro node 12. However, the use of ABSs in downlink from the macro node 12 normally results in spectral inefficiency and reduced capacity in both uplink to the macro node 12 and, in some implementations, the downlink itself.

More specifically, FIG. 3 illustrates an exemplary downlink (DL) transmission pattern at the macro node 12 including ABSs and a corresponding exemplary uplink (UL) at the macro node 12. ABSs do not include control information and also do not include data. As illustrated, downlink includes a number of ABSs arranged according to an ABS pattern. Note that the illustrated ABS pattern is exemplary. Any desired ABS pattern may be used. Because ABSs in the downlink do not contain any control information (i.e., for LTE, the ABSs do not contain the DCI, which includes the PDCCH, the Physical Hybrid-ARQ Indicator Channel (PHICH), and the Physical Control Format Indicator Channel (PCFICH)), ABSs do not contain control information to schedule transmissions in corresponding subframes of the uplink. As a result, no transmissions are scheduled for the corresponding subframes of the uplink. As illustrated, for LTE, the corresponding subframes in the uplink are subframes that occur four Transmit Time Intervals (TTIs) after the ABSs.

As illustrated in FIGS. 2 and 3, normally when using ABSs in downlink, there is spectral inefficiency due to ABSs themselves in the downlink and subframes in the uplink for which no transmissions are scheduled as a result of the ABSs in the downlink. FIG. 4 is a flow chart that illustrates the operation of the macro node 12 of FIG. 1 according to one embodiment of the present disclosure. In general, when using ABSs in the downlink, the macro node 12 operates to fill at least some of the corresponding subframes in the downlink/uplink that would normally contain no transmissions due to the lack of control information in ABSs with transmissions scheduled according to scheduling schemes that do not require control information for every subframe of the transmissions.

As illustrated, the macro node 12 applies ABSs to the downlink (step 100). The ABSs are arranged in the downlink according to a desired ABS pattern. The ABS pattern may be a predefined or predetermined ABS pattern. Alternatively, the macro node 12 may adjust the ABS pattern as discussed below. In addition, the macro node 12 identifies one or more UEs for which transmissions are to be scheduled using a scheduling scheme that does not require control information for every subframe (step 102). Note that the ordering of steps 100 and 102 may be reversed. In one embodiment, the scheduling scheme is TTI bundling. For TTI bundling, a single transmission grant to a UE is a grant for the entire TTI bundle, which for LTE is four consecutive TTIs, which is equivalent to four consecutive subframes. Thus, as discussed above, TTI bundling may be used to schedule a TTI bundle that overlaps subframes that correspond to ABSs in the downlink. In another embodiment, the scheduling scheme is a semi-persistent or persistent scheduling scheme where a single transmission grant to a UE is a grant for transmissions spanning one or more subframes at a defined periodicity. Note that TTI bundling, semi-persistent scheduling (SPS), and persistent scheduling (PS) are suitable scheduling schemes that can be used for LTE. However, these types of scheduling schemes and potentially other suitable scheduling schemes may be used if the HetNet 10 operates according to another standard.

Lastly, the macro node 12 time-aligns scheduling instants for the one or more UEs identified in step 102 with subframes that correspond to at least some of the ABSs in the downlink from the macro node 12 (step 104). More specifically, for TTI bundling, the TTI bundles for the UE(s) are time-aligned with the subframes in the uplink/downlink that correspond to ABS(s) in the downlink. Likewise, for SPS or PS, the periodic scheduling instants for the UE(s) are time-aligned with subframes in the uplink/downlink that correspond to ABSs in the downlink from the macro node 12. In one embodiment, time-alignment is performed by scheduling the transmissions for the one or more UEs to be time-aligned with ABSs in a predefined or predetermined ABS pattern.

FIG. 5 is a flow chart that illustrates the operation of the macro node 12 of FIG. 1 to provide efficient spectrum utilization for the uplink when applying ABSs in the downlink according to one embodiment of the present disclosure. In general, when using ABSs in the downlink, the macro node 12 operates to fill at least some of the corresponding subframes in the uplink that would normally contain no transmissions due to the lack of control information in the ABSs with transmissions (i.e., scheduling instants) scheduled according to scheduling schemes that do not require control information for every subframe of the transmissions.

As illustrated, the macro node **12** applies ABSs to the downlink (step **200**). The ABSs are arranged in the downlink according to a desired ABS pattern. The ABS pattern may be a predefined or predetermined ABS pattern. Alternatively, the macro node **12** may adjust the ABS pattern as discussed below. In addition, the macro node **12** identifies one or more UEs for which uplink transmissions are to be scheduled using a scheduling scheme that does not require control information for every subframe (step **202**). In other words, the scheduling scheme is any type of scheduling scheme that does not require that all subframes of the downlink include control information to schedule transmissions for corresponding subframes in the uplink. Note that the ordering of steps **200** and **202** may be reversed.

More specifically, in one embodiment, the scheduling scheme is TTI bundling. For TTI bundling, a single transmission grant to a UE is a grant for the entire TTI bundle, which for LTE is four consecutive TTIs (i.e., four consecutive subframes). Thus, TTI bundling may be used to schedule a TTI bundle in the uplink that overlaps subframes that correspond to ABSs in the downlink. In another embodiment, the scheduling scheme is a semi-persistent or persistent scheduling scheme where a single transmission grant to a UE for the uplink is a grant for transmissions spanning one or more subframes in the uplink at a defined periodicity. Note that TTI bundling, SPS, and PS are suitable scheduling schemes that can be used for LTE. However, these types of scheduling schemes and potentially other suitable scheduling schemes may be used if the HetNet **10** operates according to another standard.

Lastly, the macro node **12** time-aligns scheduling instants in the uplink for the one or more UEs identified in step **102** with subframes in the uplink that correspond to at least some of the ABSs in the downlink from the macro node **12** (step **204**). The subframes in the uplink that correspond to the ABSs in the downlink are subframes in the uplink that occur in the uplink a predefined amount of time after the corresponding ABSs in the downlink. For LTE, the corresponding subframes in the uplink are subframes that occur in the uplink four TTIs, or four subframes, after the ABSs in the downlink. More specifically, for TTI bundling, the TTI bundles for the UE(s) in the uplink are time-aligned with the subframes in the uplink that correspond to ABS(s) in the downlink. Note that when using TTI bundling, the macro node **12** may identify the UEs that are to use TTI bundling and then schedule transmissions (i.e., scheduling instants) for those UEs using a desired weighting or prioritization scheme. The weighting or prioritization scheme may consider, for example, the type of data to be transmitted. For SPS or PS, the periodic scheduling instants for the UE(s) are time-aligned with subframes in the uplink that correspond to ABSs in the downlink from the macro node **12**. In one embodiment, the ABS pattern is predetermined, and time-alignment is performed by aligning the scheduling instants with subframes in the uplink that correspond to at least some of the ABSs in the predetermined ABS pattern. In another embodiment, the ABS pattern is adjustable, and time-alignment is performed by adjusting the ABS pattern to achieve time-alignment of the scheduling instants with subframes in the uplink that correspond to at least some of the ABSs in the downlink.

FIG. **6** graphically illustrates time alignment of TTI bundles for one or more UEs and subframes in the uplink to the macro node **12** that correspond to ABSs in the downlink from the macro node **12** according to one embodiment of the process of FIG. **5**. As illustrated, the downlink (DL) from the macro node **12** includes a series of subframes including a first subframe that includes a normal transmission along with control information (e.g., DCI) that schedules a TTI bundle in the uplink (UL). The first subframe in the downlink is followed by three ABSs. Specifically, subframe **0** of the downlink is a normal transmission that includes the control information that schedules the TTI bundle in the uplink. Subframes **1**, **2**, and **3** of the downlink are ABSs. As a result of the control information, a TTI bundle (i.e., for LTE, four consecutive subframes transmitting the same data) is transmitted in the uplink starting at subframe **4** and continuing through subframe **7** of the uplink.

Normally, the ABSs in subframes **1**, **2**, and **3** of the downlink would result in no transmissions being scheduled for subframes **5**, **6**, and **7** of the uplink. However, by scheduling the TTI bundle appropriately, the TTI bundle overlaps subframes **5**, **6**, and **7** of the uplink. In other words, by scheduling the TTI bundle appropriately, subframes in the uplink that would have been unused as a result of the ABSs in the downlink are now used for transmission of the TTI bundle. In this manner, the macro node **12** provides efficient spectrum utilization in the uplink to the macro node **12** when using ABSs in the downlink from the macro node **12**.

FIG. **7** graphically illustrates time alignment of semi-persistent or persistent scheduling instants of one or more UEs and subframes in the uplink to the macro node **12** that correspond to ABSs in the downlink from the macro node **12** according to another embodiment of the process of FIG. **5**. As illustrated, the downlink (DL) from the macro node **12** includes a series of ABSs. Specifically, subframes **0**, **1**, and **2** of the downlink are ABSs. Normally, the ABSs in subframes **0**, **1**, and **2** of the downlink would result in no transmissions being scheduled for subframes **4**, **5**, and **6** of the uplink (UL). However, semi-persistent or persistent transmissions scheduled according to a semi-persistent or persistent scheduling scheme are time-aligned with subframes **4**, **5**, and **6** of the uplink. In other words, using transmission instants of UEs scheduled using semi-persistent or persistent scheduling, subframes in the uplink that would have been unused as a result of the ABSs in the downlink are now used for the transmission instants of the UEs. In this manner, the macro node **12** provides efficient spectrum utilization in the uplink to the macro node **12** when using ABSs in the downlink from the macro node **12**.

FIG. **8** is a flow chart that illustrates the operation of the macro node **12** of FIG. **1** to provide efficient spectrum utilization for the downlink when applying ABSs in the downlink according to one embodiment of the present disclosure. As discussed above, the ABSs do not include control information. In addition, for this embodiment, the ABSs preferably do not include data. In general, when using ABSs in the downlink, the macro node **12** operates to fill at least some of the ABSs in the downlink with data transmissions (i.e., scheduling instants) scheduled according to scheduling schemes that do not require control information for every subframe of the transmissions.

As illustrated, the macro node **12** applies ABSs to the downlink (step **300**). The ABSs are arranged in the downlink according to a desired ABS pattern. Again, the ABS pattern may be a predefined or predetermined ABS pattern. Alternatively, the macro node **12** may adjust the ABS pattern as discussed below. In addition, the macro node **12** identifies one or more UEs that are determined to be non-interfering with any neighboring LPNs such as the LPN **14** (step **302**). For instance, the UEs that are determined to be non-interfering may be UEs that are located near the macro node **12** as determined by, for example, received strength of signal (e.g., have a received strength of signal for the downlink from the macro node **12** that is greater than a predefined threshold). As

another example, the UEs that are determined to be non-interfering may be UEs that are located far from the LPN **14** as determined by, for example, received strength of signal (e.g., have a received strength of signal for the downlink from the LPN **14** that is less than a predefined threshold).

From among the non-interfering UEs identified in step **302**, the macro node **12** identifies one or more UEs for which downlink transmissions are to be scheduled using a scheduling scheme that does not require control information for every subframe (step **304**). In one embodiment, the scheduling scheme is SPS, PS, or a similar scheduling scheme. Note that LTE does not currently provide TTI bundling for the downlink. However, if the HetNet **10** were to operate according to a standard that did provide TTI bundling in the downlink, then the scheduling scheme may also be TTI bundling. Note that the ordering of steps **300**, **302**, and **304** may be altered (e.g., steps **302** and **304** may be performed before step **300**).

Next, the macro node **12** time-aligns scheduling instants for the one or more UEs identified in step **304** with at least some of the ABSs in the downlink from the macro node **12** (step **306**). More specifically, for SPS or PS, the periodic scheduling instants for the UE(s) are time-aligned with at least some of the ABSs in the downlink from the macro node **12**. Lastly, the macro node **12** reduces a transmit power level for downlink transmission during transmission of the scheduling instants of the UEs that are time-aligned with the ABSs in the downlink (step **308**). Notably, when reducing the transmission power, the macro node **12** preferably notifies the UEs of the reduced transmission power. This notification may be provided via, for example, Radio Resource Control (RRC) signaling. As another example, the UEs may have predefined transmit modes that operate at different power levels, where the macro node **12** may notify the UEs of the transmission power level via UE-specific reference signals.

FIG. **9** graphically illustrates time alignment of semi-persistent or persistent scheduling instants of one or more UEs and ABSs in the downlink from the macro node **12** according to one embodiment of the process of FIG. **8**. As illustrated, the downlink (DL) from the macro node **12** includes ABSs. Specifically, in this example, subframes **0** and **4** of the downlink are ABSs, which normally do not contain data and do not include control information. However, semi-persistent or persistent transmissions scheduled according to a semi-persistent or persistent scheduling scheme are time-aligned with subframes **3** through **6** of the downlink such that data is transmitted during the ABS of subframe **4**. In other words, using transmission instants of UEs scheduled using semi-persistent or persistent scheduling, subframe **4** in the downlink that would have been unused as a result of being an ABS is now used for the transmission instants of the UEs. In this manner, the macro node **12** provides efficient spectrum utilization in the downlink from the macro node **12** when using ABSs in the downlink from the macro node **12**.

FIG. **10** illustrates a HetNet **26** according to another embodiment of the present disclosure. In this embodiment, the HetNet **26** includes a macro node **28** that serves a corresponding macro cell **30** and a Closed Subscriber Group (CSG) femto node **32** (hereinafter femto node **32**) that serves subscribers in a corresponding CSG femto cell **34** (hereinafter femto cell **34**). In the illustrated example, a UE **36** is a subscriber of the femto node **32** and, as such, the UE **36** is served by the femto node **32**. However, UE **38** is not a subscriber of the femto node **32** and, as such, the UE **38** is served by the macro node **28**. Therefore, the macro node **28** operates to serve UEs in the femto cell **34** that are not subscribers of the femto node **32** as well as UEs, such as the UE **40**, that are otherwise located in the macro cell **30**. Preferably, transmissions to and from the macro node **28** are synchronized with transmissions to and from the femto node **32**.

In this embodiment, the femto node **32** applies ABSs in the downlink from the femto node **32** to the subscribers of the femto node **32** located in the femto cell **34**. In one embodiment, the femto node **32** uses the process described above with respect to FIGS. **4** through **6** to time-align scheduling instants scheduled according to a scheduling scheme that does not require control information for each subframe and subframes in the uplink to the femto node **32** that correspond to ABSs in the downlink from the femto node **32**. As discussed above, the scheduling scheme may be TTI bundling, SPS, PS, or the like. As such, subframes in the uplink to the femto node **32** for which no transmissions would have been scheduled as a result of the ABSs in the downlink from the femto node **32** are used, thereby improving the spectral efficiency of the femto node **32**. In addition or alternatively, the femto node **32** may use the process described above with respect to FIGS. **8** and **9** to time-align scheduling instants for the downlink scheduled according to a scheduling scheme that does not require control information for each subframe and at least some of the ABSs in the downlink from the femto node **32**. As discussed above, the scheduling scheme may be TTI bundling, SPS, PS, or the like. As such, at least some of the ABSs in the downlink that would have otherwise included no data are used, thereby improving the spectral efficiency of the femto node **32**.

FIG. **11** illustrates a HetNet **42** according to another embodiment of the present disclosure. In this embodiment, the HetNet **42** includes a macro node **44** that serves a corresponding macro cell **46**, a CSG femto node **48** (hereinafter femto node **48**) that serves subscribers in a corresponding CSG femto cell **50** (hereinafter femto cell **50**), and a pico node **52** that serves a corresponding pico cell **54** and expansion region **56**. In the illustrated example, a UE **58** is a subscriber of the femto node **48** and, as such, the UE **58** is served by the femto node **48**. However, UE **60** is not a subscriber of the femto node **48** and, as such, the UE **60** is served by the macro node **44**. UE **62** is located in the pico cell **54** and is therefore served by the pico node **52**. The macro node **44** operates to serve UEs in the femto cell **50** that are not subscribers of the femto node **48** as well as UEs, such as UE **64**, that are otherwise located in the macro cell **46** but outside of the pico cell **54** and the expansion region **56** of the pico node **52**. Preferably, transmissions to and from the macro node **44** are synchronized with transmissions to and from the femto node **48** and transmissions to and from the pico node **52**.

In this embodiment, the femto node **48** applies ABSs in the downlink from the femto node **48** to the subscribers of the femto node **48** located in the femto cell **50**. In one embodiment, the femto node **48** uses the process described above with respect to FIGS. **4** through **6** to time-align scheduling instants scheduled according to a scheduling scheme that does not require control information for each subframe and subframes in the uplink to the femto node **48** that correspond to ABSs in the downlink from the femto node **48**. As discussed above, the scheduling scheme may be TTI bundling, SPS, PS, or the like. As such, subframes in the uplink to the femto node **48** for which no transmissions would have been scheduled as a result of the ABSs in the downlink from the femto node **48** are used, thereby improving the spectral efficiency of the femto node **48**. In addition or alternatively, the femto node **48** may use the process described above with respect to FIGS. **8** and **9** to time-align scheduling instants for the downlink scheduled according to a scheduling scheme that does not require control information for each subframe and at least some of the ABSs in the downlink from the femto

node **48**. As discussed above, the scheduling scheme may be TTI bundling, SPS, PS, or the like. As such, at least some of the ABSs in the downlink that would have otherwise included no data are used, thereby improving the spectral efficiency of the femto node **48**.

FIG. **12** illustrates a HetNet that provides uplink interference cancellation according to one embodiment of the present disclosure. As illustrated, the HetNet includes a macro node serving a corresponding macro cell, a LPN serving a LPN cell, and UEs, namely, UE**1** and UE**2**. The macro node sends PDCCH information to UE**2** to schedule a transmission for UE**2** in the uplink to the macro node (step **400**). Preferably, the PDCCH schedules a TTI bundle for UE**2** in the uplink to the macro node. However, other types of scheduling such as, for example, SPS or PS may be used. In addition, the macro node sends the PDCCH information for UE**2** to the LPN via an inter-node communication interface (e.g., an X2 interface or other backhaul network interface) (step **402**). Thereafter, UE**2** sends a transmission using the scheduled resources of the uplink to the macro node (step **404**). Again, preferably, the transmission is a TTI bundle using the scheduled resources of the uplink to the macro node. At that same time, UE**1** transmits data to the LPN using the same resources of the uplink to the LPN (step **406**).

In order to cancel interference for the transmission from UE**1** to the LPN, the LPN stores the uplink transmission from UE**1** (step **408**). In addition, the LPN receives the transmission from UE**2** in the uplink to the macro node and processes the transmission to train one or more parameters for interference cancellation for canceling the interference caused in the uplink transmission from UE**1** (step **410**). More specifically, preferably, the transmission from UE**2** is a TTI bundle. The TTI bundle includes four transmissions of the same data, but the four transmissions are coded differently (i.e., Incremental Redundancy, in order to obtain coding gains). If the LPN is able to decode the first transmission of the TTI bundle correctly, the LPN can then train the parameters for the interference cancellation using the remaining transmissions in the TTI bundle, which use the same physical resource blocks but using different known coding. Note, however, this same process may be used even if the LPN needs the first two or even three of the transmissions to successfully decode the data, where the remaining transmissions after the successful decode are used to train the parameters for interference cancellation. A similar process may be used to train the interference cancellation using SPS or PS. Lastly, the LPN performs interference cancellation for the stored uplink transmission from UE**1** using the parameters determined in step **410** (step **412**). In this manner, interference cancellation is performed to remove, or at least substantially remove, the interference in the uplink transmission from UE**1** to the LPN caused by the uplink transmission from UE**2** to the macro node.

FIG. **13** illustrates a HetNet that provides downlink interference cancellation according to one embodiment of the present disclosure. As illustrated, the HetNet includes a macro node serving a corresponding macro cell, a LPN serving a LPN cell, and UEs, namely, UE**1** and UE**2**. The macro node sends PDCCH information to UE**2** to a repetitive downlink transmission (e.g., a TTI bundle or an ARQ retransmission) for UE**2** in the downlink to the macro node (step **500**). In addition, the macro node sends the PDCCH information for UE**2** to the LPN via an inter-node communication interface (e.g., an X2 interface or other backhaul network interface) (step **502**). The LPN then sends the PDCCH information for UE**2** to UE**1** via, for example, RRC signaling (step **504**). Thereafter, the macro node transmits to UE**1** using the scheduled resources of the downlink from the macro node (step **506**). At that same time, the LPN transmits data to UE**1** using the same resources of the downlink from the LPN (step **508**).

In order to cancel interference for the downlink transmission from the LPN to UE**1**, UE**1** stores the downlink transmission from the LPN (step **510**). In addition, UE**1** receives the downlink transmission from the macro node to UE**2** using the PDCCH information received from the LPN and processes the downlink transmission to train one or more parameters for interference cancellation (step **512**). Here, the interference cancellation is to cancel interference in the downlink transmission to UE**1** resulting from the downlink transmission to UE**2**. Lastly, UE**1** performs interference cancellation for the stored downlink transmission from the LPN using the parameters determined in step **512** (step **514**). In this manner, interference cancellation is performed to remove, or at least substantially remove, the interference in the downlink transmission from the LPN to UE**1** caused by the downlink transmission from the macro node to UE**2**.

FIG. **14** is a block diagram of a macro node **66** according to one embodiment of the present disclosure. The macro node **66** may be the macro node **12** of FIG. **1**, the macro node **28** of FIG. **10**, or the macro node **44** of FIG. **11**. The macro node **66** includes a transceiver subsystem **68**, an inter-node communication interface **70**, and a processing subsystem **72**. The transceiver subsystem **68** generally includes analog and, in some embodiments, digital components for sending and receiving communications to and from UEs within the macro cell of the macro node **66**. The inter-node communication interface **70** generally includes analog and, in some embodiments, digital components for sending and receiving communications to and from other nodes (i.e., other macro nodes and, in some embodiments, neighboring pico nodes and/or neighboring femto nodes). From a communications protocol view, the transceiver subsystem **68** and the inter-node communication interface **70** implement at least part of Layer 1 (i.e., the Physical or "PHY" Layer). The processing subsystem **72** generally implements any remaining portion of Layer 1 as well as functions for higher layers in the wireless communications protocol (e.g., Layer 2 (data link layer), Layer 3 (network layer), etc.). Of course, the detailed operation for each of the functional protocol layers, and thus the transceiver subsystem **68**, the inter-node communication interface **70**, and the processing subsystem **72**, will vary depending on both the particular implementation as well as the standard or standards supported by the macro node **66**. In some embodiments, the processing subsystem **72** generally operates to time-align scheduling instants with subframes in the uplink that correspond to ABSs in the downlink and/or time-align scheduling instants in the downlink with ABSs in the downlink, as described above.

Those skilled in the art will appreciate that the block diagram of the macro node **66** necessarily omits numerous features that are not necessary to a complete understanding of this disclosure. For instance, although all of the details of the processing subsystem **72** are not illustrated, those skilled in the art will recognize that the processing subsystem **72** comprises one or several general-purpose or special-purpose microprocessors or other microcontrollers programmed with suitable software and/or firmware to carry out some or all of the functionality of the macro node **66** described herein. In addition or alternatively, the processing subsystem **72** may comprise various digital hardware blocks (e.g., one or more Application Specific Integrated Circuits (ASICs), one or more off-the-shelf digital and analog hardware components, or a combination thereof) configured to carry out some or all of the functionality of the macro node **66** described herein.

FIG. **15** is a block diagram of a femto node **74** according to one embodiment of the present disclosure. The femto node **74** may be the femto node **32** of FIG. **10** or the femto node **48** of FIG. **11**. The femto node **74** includes a transceiver subsystem **76**, an inter-node communication interface **78**, and a processing subsystem **80**. The transceiver subsystem **76** generally includes analog and, in some embodiments, digital components for sending and receiving communications to and from subscribers within the femto cell of the femto node **74**. The inter-node communication interface **78** generally includes analog and, in some embodiments, digital components for sending and receiving communications to and from other nodes (i.e., macro nodes and, in some embodiments, neighboring pico nodes and/or neighboring femto nodes). From a communications protocol view, the transceiver subsystem **76** and the inter-node communication interface **78** implement at least part of Layer 1 (i.e., the Physical or "PHY" Layer). The processing subsystem **80** generally implements any remaining portion of Layer 1 as well as functions for higher layers in the wireless communications protocol (e.g., Layer 2 (data link layer), Layer 3 (network layer), etc.). Of course, the detailed operation for each of the functional protocol layers, and thus the transceiver subsystem **76**, the inter-node communication interface **78**, and the processing subsystem **80**, will vary depending on both the particular implementation as well as the standard or standards supported by the femto node **74**. In some embodiments, the processing subsystem **80** generally operates to time-align scheduling instants with subframes in the uplink that correspond to ABSs in the downlink and/or time-align scheduling instants in the downlink with ABSs in the downlink, as described above.

Those skilled in the art will appreciate that the block diagram of the femto node **74** necessarily omits numerous features that are not necessary to a complete understanding of this disclosure. For instance, although all of the details of the processing subsystem **80** are not illustrated, those skilled in the art will recognize that the processing subsystem **80** comprises one or several general-purpose or special-purpose microprocessors or other microcontrollers programmed with suitable software and/or firmware to carry out some or all of the functionality of the femto node **74** described herein. In addition or alternatively, the processing subsystem **80** may comprise various digital hardware blocks (e.g., one or more ASICs, one or more off-the-shelf digital and analog hardware components, or a combination thereof) configured to carry out some or all of the functionality of the femto node **74** described herein.

FIG. **16** is a block diagram of a UE **82** according to one embodiment of the present disclosure. The UE **82** may be any one of the UEs of FIGS. **1**, **10**, and **11**. The UE **82** includes a transceiver subsystem **84** and a processing subsystem **86**. The transceiver subsystem **84** generally includes analog and, in some embodiments, digital components for sending and receiving communications to and from a macro node, a femto node, or a pico node. From a communications protocol view, the transceiver subsystem **84** implements at least part of Layer 1 (i.e., the Physical or "PHY" Layer). The processing subsystem **86** generally implements any remaining portion of Layer 1 as well as functions for higher layers in the wireless communications protocol (e.g., Layer 2 (data link layer), Layer 3 (network layer), etc.). Of course, the detailed operation for each of the functional protocol layers, and thus the transceiver subsystem **84** and the processing subsystem **86**, will vary depending on both the particular implementation as well as the standard or standards supported by the UE **82**.

Those skilled in the art will appreciate that the block diagram of the UE **82** necessarily omits numerous features that are not necessary to a complete understanding of this disclosure. For instance, although all of the details of the processing subsystem **86** are not illustrated, those skilled in the art will recognize that the processing subsystem **86** comprises one or several general-purpose or special-purpose microprocessors or other microcontrollers programmed with suitable software and/or firmware to carry out some or all of the functionality of the UE **82** described herein. In addition or alternatively, the processing subsystem **80** may comprise various digital hardware blocks (e.g., one or more ASICs, one or more off-the-shelf digital and analog hardware components, or a combination thereof) configured to carry out some or all of the functionality of the UE **82** described herein.

The following acronyms are used throughout this disclosure.

ABS Almost Blank Subframe
ARQ Automatic Repeat Request
ASIC Application Specific Integrated Circuit
BS Base Station
CRS Common, or Cell-Specific, Reference Signal
CSG Closed Subscriber Group
dBm Decibel-Milliwatt
DCI Downlink Control Information
DL Downlink
HetNet Heterogeneous Network
LP Low Power
LPN Low Power Node
LTE Long Term Evolution
PCFICH Physical Control Format Indicator Channel
PDCCH Physical Downlink Control Channel
PDSCH Physical Downlink Shared Channel
PHICH Physical Hybrid-ARQ Indicator Channel
PS Persistent Scheduling
QoS Quality-of-Service
RE Range Extension
RRC Radio Resource Control
RSRP Reference Signal Received Power
RSS Received Signal Strength
SPS Semi-Persistent Scheduling
TTI Transmit Time Interval
UE User Equipment Device
UL Uplink

Those skilled in the art will recognize improvements and modifications to the preferred embodiments of the present disclosure. All such improvements and modifications are considered within the scope of the concepts disclosed herein and the claims that follow.

What is claimed is:

**1**. A method of operation of an access node in a cellular communication network, comprising:

applying almost blank subframes in a downlink from the access node;

identifying one or more user equipment devices for which transmissions are to be scheduled using a scheduling scheme that does not require control information for every subframe scheduled by the scheduling scheme; and

time-aligning scheduling instants of the one or more user equipment devices and subframes that correspond to at least some of the almost blank subframes in the downlink.

**2**. The method of claim **1** wherein:

identifying the one or more user equipment devices comprises identifying one or more user equipment devices for which transmissions are to be scheduled in an uplink to the access node using the scheduling scheme that does

not require control information for every subframe scheduled by the scheduling scheme; and

time-aligning the scheduling instants of the one or more user equipment devices and subframes that correspond to the at least some of the almost blank subframes in the downlink comprises time-aligning the scheduling instants of the one or more user equipment devices for the uplink with subframes in the uplink that correspond to the at least some of the almost blank subframes in the downlink.

**3**. The method of claim **2** wherein the almost bank subframes in the downlink do not contain control information for corresponding subframes in the uplink.

**4**. The method of claim **2** wherein the subframes in the uplink that correspond to the at least some of the almost blank subframes in the downlink are subframes in the uplink that occur a predefined amount of time after the at least some of the almost blank subframes in the downlink.

**5**. The method of claim **2** wherein the subframes in the uplink that correspond to the at least some of the almost blank subframes in the downlink are subframes in the uplink that occur four transmit time intervals after the at least some of the almost blank subframes in the downlink.

**6**. The method of claim **2** wherein the scheduling scheme is TTI bundling.

**7**. The method of claim **6** wherein time-aligning the scheduling instants of the one or more user equipment devices for the uplink with subframes in the uplink that correspond to the at least some of the almost blank subframes in the downlink comprises, for each user equipment device of the one or more user equipment devices, scheduling a transmission of a TTI bundle for subframes of the uplink that include at least one subframe in the uplink that corresponds to an almost blank subframe in the downlink.

**8**. The method of claim **6** wherein the access node is a macro node, and the method further comprises providing control information related to scheduling of a TTI bundle for a user equipment device of the one or more user equipment devices to a neighboring low power node in the cellular communication network.

**9**. The method of claim **8** wherein the neighboring low power node utilizes the control information to receive the TTI bundle from the user equipment device in the uplink to the macro node and perform interference cancellation for an uplink from a second user equipment device to the neighboring low power node.

**10**. The method of claim **2** wherein the scheduling scheme is a semi-persistent scheduling scheme.

**11**. The method of claim **10** wherein time-aligning the scheduling instants of the one or more user equipment devices for the uplink with subframes in the uplink that correspond to the at least some of the almost blank subframes in the downlink comprises, for each user equipment device of the one or more user equipment devices, scheduling a plurality of semi-persistent scheduling instants for the user equipment device such that at least a subset of the plurality of semi-persistent scheduling instants for the user equipment device are scheduled for subframes in the uplink that correspond to almost blank subframes in the downlink.

**12**. The method of claim **2** wherein the scheduling scheme is a persistent scheduling scheme.

**13**. The method of claim **12** wherein time-aligning the scheduling instants of the one or more user equipment devices for the uplink with subframes in the uplink that correspond to the at least some of the almost blank subframes in the downlink comprises, for each user equipment device of the one or more user equipment devices, scheduling a plurality of persistent scheduling instants for the user equipment device such that at least a subset of the plurality of persistent scheduling instants for the user equipment device are scheduled for subframes in the uplink that correspond to almost blank subframes in the downlink.

**14**. The method of claim **1** wherein:

identifying the one or more user equipment devices comprises:

identifying one or more non-interfering user equipment devices that are determined to not interfere with any neighboring pico nodes; and

identifying one or more user equipment devices from the one or more non-interfering user equipment devices for which downlink transmissions are to be scheduled using the scheduling scheme that does not require control information for every subframe scheduled by the scheduling scheme; and

time-aligning the scheduling instants of the one or more user equipment devices and subframes that correspond to the at least some of the almost blank subframes in the downlink comprises time-aligning the scheduling instants of the one or more user equipment devices for the downlink with the at least some of the almost blank subframes in the downlink.

**15**. The method of claim **14** further comprising reducing a transmit power level for the downlink during transmission of the at least some of the almost blank subframes in the downlink.

**16**. The method of claim **14** wherein the almost bank subframes in the downlink do not contain control information.

**17**. The method of claim **14** wherein the scheduling scheme is a semi-persistent scheduling scheme.

**18**. The method of claim **17** wherein time-aligning the scheduling instants of the one or more user equipment devices for the downlink with the at least some of the almost blank subframes in the downlink comprises, for each user equipment device of the one or more user equipment devices, scheduling a plurality of semi-persistent scheduling instants for the user equipment device such that at least a subset of the plurality of semi-persistent scheduling instants for the user equipment device are scheduled for almost blank subframes in the downlink.

**19**. The method of claim **17** wherein time-aligning the scheduling instants of the one or more user equipment devices for the downlink with the at least some of the almost blank subframes in the downlink comprises, for each user equipment device of the one or more user equipment devices, scheduling a plurality of persistent scheduling instants for the user equipment device such that at least a subset of the plurality of persistent scheduling instants for the user equipment device are scheduled for almost blank subframes in the downlink.

**20**. The method of claim **14** wherein the scheduling scheme is a persistent scheduling scheme.

**21**. The method of claim **1** wherein the access node is a macro node.

**22**. The method of claim **21** wherein transmissions for the macro node are synchronized with transmissions for a neighboring low power node.

**23**. The method of claim **1** wherein the access node is a closed subscriber group femto node.

**24**. The method of claim **23** wherein transmissions for the closed subscriber group femto node are synchronized with transmissions for a neighboring macro node.

**25**. The method of claim **1** wherein the almost blank subframes in the downlink are arranged according to a predetermined almost blank subframe pattern, and time-aligning the

scheduling instants of the one or more user equipment devices and subframes that correspond to the at least some of the almost blank subframes in the downlink comprises scheduling the scheduling instants of the one or more user equipment devices according to the predetermined almost blank subframe pattern.

**26**. The method of claim **1** wherein time-aligning the scheduling instants of the one or more user equipment devices and subframes that correspond to the at least some of the almost blank subframes in the downlink comprises adjusting an almost blank subframe pattern for the almost blank subframes in the downlink such that the scheduling instants of the one or more user equipment devices are time-aligned with subframes that correspond to the at least some of the almost blank subframes in the downlink.

**27**. An access node in a cellular communication network, comprising:

a transceiver subsystem adapted to provide a downlink and an uplink to user equipment devices served by the access node; and

a processing subsystem associated with the transceiver subsystem and adapted to:

apply almost blank subframes in the downlink from the access node;

identify one or more user equipment devices for which transmissions are to be scheduled using a scheduling scheme that does not require control information for every subframe scheduled by the scheduling scheme; and

time-align scheduling instants of the one or more user equipment devices and subframes that correspond to at least some of the almost blank subframes in the downlink.

**28**. The access node of claim **27** wherein:

the one or more user equipment devices are one or more user equipment devices for which uplink transmissions are to be scheduled in an uplink to the access node using the scheduling scheme that does not require control information for every subframe scheduled by the scheduling scheme; and

the scheduling instants of the one or more user equipment devices are scheduling instants of the one or more user equipment devices for the uplink that are time-aligned with subframes in the uplink that correspond to the at least some of the almost blank subframes in the downlink.

**29**. The access node of claim **28** wherein the almost bank subframes in the downlink do not contain control information for corresponding subframes in the uplink.

**30**. The access node of claim **28** wherein the subframes in the uplink that correspond to the at least some of the almost blank subframes in the downlink are subframes in the uplink that occur a predefined amount of time after the at least some of the almost blank subframes in the downlink.

**31**. The access node of claim **28** wherein the subframes in the uplink that correspond to the at least some of the almost blank subframes in the downlink are subframes in the uplink that occur four transmit time intervals after the at least some of the almost blank subframes in the downlink.

**32**. The access node of claim **28** wherein the scheduling scheme is TTI bundling.

**33**. The access node of claim **28** wherein the scheduling scheme is a semi-persistent scheduling scheme.

**34**. The access node of claim **28** wherein the scheduling scheme is a persistent scheduling scheme.

**35**. The access node of claim **27** wherein the access node is a macro node, and:

the one or more user equipment devices are one or more user equipment devices determined to not interfere with any neighboring pico nodes of the macro node and for which downlink transmissions are to be scheduled using the scheduling scheme that does not require control information for every subframe scheduled by the scheduling scheme; and

the scheduling instants of the one or more user equipment devices are time-aligned with the at least some of the almost blank subframes in the downlink.

**36**. The access node of claim **35** wherein the processing subsystem is further adapted to reduce a transmit power level for the downlink during transmission of the almost blank subframes in the downlink.

**37**. The access node of claim **35** wherein the almost bank subframes in the downlink do not contain control information.

**38**. The access node of claim **27** wherein the scheduling scheme is a semi-persistent scheduling scheme.

**39**. The access node of claim **27** wherein the scheduling scheme is a persistent scheduling scheme.

**40**. The access node of claim **27** wherein the access node is a macro node.

**41**. The access node of claim **40** wherein transmissions for the macro node are synchronized with transmissions for a neighboring low power node.

**42**. The access node of claim **27** wherein the access node is a closed subscriber group femto node.

**43**. The access node of claim **42** wherein transmissions for the closed subscriber group femto node are synchronized with transmissions for a neighboring macro node.

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